Some Test Data on Fireproof Floor Construction

Relating to Cinder Concrete Terra Cotta and Gypsum

CLINTON WIRE CLOTH COMPANY
Clinton, Mass.

A Fire, Load and Water Test Comparing the Fireproofing Properties of Cinder Concrete, Terra Cotta and Gypsum Floor Slabs

ON July 30, 1913, a test was conducted at the Columbia Fire Testing Station, Greenpoint, Brooklyn, N. Y., upon so-called fireproof floors of three different types.

These floors were constructed side by side and subjected simultaneously to the regulation fire, load and water test as prescribed by the Building Department of New York City. The test was, therefore, a comparative one, showing the behavior of these different types of construction under the same conditions of test, and for this reason the results are both significant and interesting.

The specimens included a floor slab of cinder concrete, one of terra cotta and one of gypsum and shavings. Each of these types of construction have, from time to time, been tested separately, but this was the first instance where these different materials were tested side by side and subjected to the same identical conditions.

The slabs were erected by experienced workmen and every precaution was taken to have the constructions similar to those employed in actual practice. The gypsum slab was erected by an experienced man in the employ of the United States Gypsum Company. The cinder concrete slab was erected by workmen experienced in that type of construction, and the terra cotta slab was laid under the supervision of a man who has had years of experience in that particular kind of work.

The cinder concrete slab and terra cotta slab when tested had been in place practically 30 days, while the gypsum slab had an age of only 14 days. In analyzing the results of the test, it should be noted that the age of the gypsum slab was thus about one-half the age of the other slabs. This was due to a misunderstanding at the time the floors were originally constructed, resulting in the use of unsuitable materials for the gypsum floor. About 2 weeks after the floors were constructed, it was, therefore, deemed advisable to remove the gypsum floor and construct a new one, thus giving this slab an age of only 14 days at the time the test was made. Owing to the short time which the gypsum floor had been in place, this slab was protected by having the under side completely covered with plaster.

The requirements of the test called for an average temperature of 1700° Fahr., maintained for 4 hours against the under side of the slabs, the slabs at the same time carrying a load of 150 pounds per square foot. Owing to the age of the gypsum slab, this slab was given an initial load of only 75 pounds per square

foot. At the end of 4 hours, the under sides of the slabs, while hot, were subjected to water pressure of about 60 pounds per square inch through a standard fire nozzle, 1⅛″ in diameter. This water was applied for 5 minutes. The top of the floor was then flooded at low pressure and the under surface of the slabs again subjected for 5 minutes to 60 pounds pressure from the hose. On the following day after the floors had cooled, they were then loaded with 600 pounds per square foot and the deflections were recorded.

The test proved that the cinder concrete floor went through the entire test practically uninjured and sustained the final loading of 600 pounds per square foot with a deflection of only $\frac{9}{32}$ of an inch.

The gypsum slab suffered a loss of all material below the reinforcement at the end of the water test and failed before the after load of 600 pounds was reached.

The terra cotta floor showed a splitting and breaking up of the lower webs of a number of the blocks when the water was applied, and a destruction of other lower webs under the application of the after load of 600 pounds. Careful examination of this arch at the conclusion of the test revealed the fact that more than 75% of the lower surface of the arch had been destroyed. Practically the entire load was being carried by the central webs and the upper faces of the blocks, and even though these were sufficient to carry the desired load, the fact remains that in an actual building considerable expense would be involved in order to restore such a floor to a suitable structural condition by furring, lathing and plastering the entire lower surface.

The test was conducted by Mr. Harold Perrine, of the University of Columbia, and his report, accompanied with drawings and photographs, explains fully the details of construction, method of testing and results obtained.

In connection with the accompanying drawings and photographs, the comments in red are made editorially, and are not a part of Mr. Perrine's report.

REPORT

OF

A Fire, Load and Water Test Made Upon Cinder Concrete, Terra Cotta and Gypsum Floor Arches

INSTALLED BY

Albert Oliver

101 Park Avenue, New York City

AT THE

Columbia Fire Testing Station

Greenpoint, Brooklyn, N. Y.

July 29 — Aug. 1, 1913

TESTED BY

Harold Perrine, C.E.

In co-operation with the Bureau of Buildings
New York City

Introduction

THE system to be tested forms the roof of the test house, which structure is essentially a cinder-concrete oven of permanent construction. Properly supported upon piers 2½ feet from the ground is a grate composed of railroad rails and wire mesh, about 280 square feet in area. The vertical distance from the grate to the roof is about 9½ feet. The floor system to be tested is supported by steel I-beams resting on the tops of the walls, spaced at distances suitable to the span or spans under test, and having a clear span themselves of about 14 feet. Ample draft openings and flues are provided to facilitate the control of the fire, their location being readily seen in Photo 10.

The structure, as well as the methods used in the herein-described test, conforms with the specifications adopted by the Bureaus of Buildings of the City of New York and by the American Society for Testing Materials.

Method of Construction

The floor system under test was comprised of three separate and distinct types of arches, *i.e.*, cinder concrete, terra cotta and gypsum.

In the first or west bay was installed a 4″ slab, 5′ 3″ in length, of 1 part Pennsylvania Portland Cement, 2 parts Cowe Bay Sand and 5 parts clean, hard-coal steam cinders, mixed medium wet, reinforced with Clinton Electrically Welded Wire reinforcement, 4″ x 12″, No. 6 x No. 10 wires, of 75,700 pounds per square inch tensile strength, every sixth wire clinched over beam flange covered with a 2″, 1–10 cinder fill (Photo 4). Age on day of test, 29 days.

In the second bay was built a side construction terra cotta arch 5′ 3″ in length, of "Natco" 10″ tile 8″ x 10″ x 12″, 6 hole ⅝″ web laid up wet in 1–3 Portland Cement mortar, fairly well grouted between blocks, but with no mortar between skew-backs and surfaces of supporting I-beams (Photos 1 and 2), all covered above with a 4″, 1–10 cinder fill (Photo 3). Age on day of test, 29 days.

The third 5′ 3″ span was composed of a 4″ slab of a mixture of gypsum and wood shavings, furnished by the United States Gypsum Company, reinforced with the identical type of Clinton wire mentioned above, every wire clinched over beam flanges and covered with a 2″, 1–10 cinder fill (Photos 5 and 6). Age on day of test, 14 days.

Each supporting beam was protected by the material comprising the adjoining arch.

One-half the under surface of each of the first two arches was plastered with two coats, while the gypsum slab was plastered throughout its entire length (Photos 7 and 8).

For details of construction see attached blueprint. The soffits of the I's were surrounded by 10″ x 12″, No. 12 x No. 12 Clinton wire.

Estimated weight, dry, of cinder slab material, equals 98 pounds per cubic foot.

Estimated weight, dry, of gypsum slab material, equals 70 pounds per cubic foot.

Purpose of the Test

The purpose of the test is to determine the effect of a continuous fire below the floor lasting 4 hours, at an average temperature of 1700° F., a temperature generally conceded to be that of a burning building, the floor carrying at the same time a distributed load of 150 pounds per square foot. At the end of the 4 hours the under side of the floor, while still red hot, is subjected to a 1⅛″ stream of cold water through a hose at short range, under a 60-pound pressure, for 5 minutes; the upper side of the floor is then flooded with water at low pressure, and afterwards the stream is applied at full pressure to the under side for 5 minutes longer. Deflections of beams and floor are measured continuously during the test. On the following day, when the floor is cool, the load is increased to 600 pounds per square foot, and deflections noted.

Load

Pig iron, stacked in segregated piles to eliminate arching, was the material used for load.

During the fire the cinder concrete and terra cotta arches carried 150 pounds per square foot, but the gypsum only 75 pounds per square foot.

Temperature

The temperature of the fire was obtained by three electric pyrometer couples suspended through the floor from above and hanging about 6″ below the ceiling. The locations of the couples are indicated on the plan of the building. Readings were made upon each couple every 3 minutes.

The fuel used was dry cord wood, one-half oak and one-half pine, the frequency of firing being determined by the temperature of the test chamber. The "Log of Temperature Readings," together with plotted curve, is attached.

Deflections

Deflections which occurred during the test were measured by a Y-level reading upon rods located at the ends and middle of each beam and at points over the centers of the slabs. "The Deflection Diagram" shows the relative position of the arches graphically at different periods.

Water

Water was applied by firemen with an engine detailed from Fire Station No. 238, Greenpoint, Brooklyn.

A pressure of well over 60 pounds was maintained at the nozzle. The stream was thrown back and forth over the ceiling and not allowed to strike continuously in one spot. The total time of the two applications at full pressure was 10 minutes.

Results of Tests

GENERAL OBSERVATIONS

Day — Fair.

Temperature — 95°.

Age of cinder and terra cotta floors — 29 days.

Age of gypsum arch — 14 days.

EFFECT OF WORKING LOAD

None of the arches showed appreciable deflection under initial load, *i.e.*, cinder concrete and terra cotta, 150 pounds per square foot; gypsum, 75 pounds per square foot.

EFFECT OF FIRE AND WATER

Cinder Concrete. The combined effect of fire and water was to remove the plaster entirely from the slab, leaving the concrete itself in excellent condition. It was only in a region near its center, in order to strike which the stream had to be elevated to nearly a vertical position, and consequently causing maximum punishment that the surface was slightly pitted (Photo 14).

The protection to the deep supporting I-beam naturally suffered more severely. Possibly about 5% of the lower flange was exposed with rather deep-seated cracks running a foot or so in both directions from the stripped portion. The remainder of the protection was deeply scored except for about 18″ at the front of the house where the water could not strike it. There it had retained its original sharp edges (Photos 14 and 15). The maximum deflection observed at the center of the slab at end of fire was $\frac{3}{8}$″.

Terra Cotta. About 80% of one beam protection, including many of the bottoms of the skew-backs, 10% of the other beam protection, and the lower faces of six arch blocks were knocked off during fire and water application (Photos 15, 16, and 17).

At completion of load test the under surface of the arch was examined carefully. It was found that well over 75% of the lower faces were unsound, portions of which could be easily removed by hand. Photo 21 was taken after this examination. Practically the entire load was being carried by the central webs and upper faces of the blocks, many of the lower faces being entirely loose, but keyed in by the remaining mortar joints.

This arch had attained a maximum deflection at the end of the fire of $1\frac{3}{16}$″.

Gypsum. It will be noted on examination of Photo 16 that the protection to the reinforcement and to the supporting I-beam flanges in this bay was entirely removed where the water had full play. Toward the front of the house, where this condition did not obtain, the gypsum covering remained. The material above the wires was softened, deeply scored, and presented a discolored, smoky appearance. Four hours of fire produced a total deflection of only $\frac{1}{16}''$.

Conducted Heat. Thermo-couples were inserted in the concrete and gypsum arches from the top through the cinder fill and into the slab to within $1\frac{1}{2}''$ of the bottom. Readings were taken from time to time throughout the fire, with the result that after 4 hours' duration the maximum readings were as follows:

Cinder concrete = 620° F.
Gypsum = 229° F.

Effect of Cooling. Both the cinder and terra cotta arches recovered after cooling, whereas the gypsum settled somewhat. See attached deflection table (Appendix III).

Effect of Load. The cinder slabs withstood the load of 600 pounds per square foot, with slightly over $\frac{1}{4}''$ deflection.

A deflection of less than $\frac{3}{4}''$ was noted in loading the terra cotta arch to this amount. After release of load, the camber of the arch could be plainly seen by sighting along the lower flanges.

When the load upon the gypsum slabs had been increased to 450 pounds per square foot, the total deflection was $\frac{5}{8}''$. At 496 pounds per square foot, failure occurred, and the slab was propped from beneath to prevent its total destruction.

Résumé

The installation of the Cinder Concrete and Terra Cotta Arches was witnessed by

Mr. J. C. Snackenberg, Bureau of Buildings, Brooklyn
Mr. Edw. Wilkinson, Bureau of Buildings, Brooklyn
Mr. Geo. E. Strehan, Bureau of Buildings, Manhattan
Mr. Thos. Heatley, Bureau of Buildings, Bronx
Mr. A. C. Siebert, Bureau of Buildings, Queens
Mr. Albert Oliver
Mr. A. E. Klotz

The installation of the Gypsum Arch was witnessed by

Mr. Edw. Wilkinson, Bureau of Buildings, Brooklyn
Mr. Thos. Heatley, Bureau of Buildings, Bronx
Mr. A. C. Siebert, Bureau of Buildings, Queens
Mr. Albert Oliver
Mr. A. E. Klotz
Mr. V. G. Marani

The following were present on July 30, during fire and water test:

Mr. D. J. Havens	Representing	Rapp Construction Co.
Mr. L. M. Grove	,,	Berger Manufacturing Co.
Mr. R. W. Van Horn	,,	Berger Manufacturing Co.
Mr. F. H. Keese	,,	Cass Gilbert
Mr. G. A. Rappold	,,	Raymond F. Almirall
Mr. Otto David	,,	J. Kresse Co.
Mr. W. R. Rodrigues	,,	Jos. Bauer
Mr. J. F. Walsh	,,	J. F. Walsh & Bro.
Mr. Franklin B. Huntington	,,	Hoppin & Koen
Mr. W. A. Robertson	Chief Inspector, Tenement House Department	
Mr. P. H. Bevier	Representing	National Fireproofing Co.
Mr. Homer A. Ried, C.E.		
Mr. Chas. F. Varney	,,	Igoe Bros.
Mr. Peter Igoe		
Mr. Fred B. Lincoln	,,	*Concrete-Cement Age*
Mr. R. B. Sears	Editor	*Cement*
Mr. Geo. A. Moore		
Mr. W. Mortensen	Representing	Mortensen & Co.
Mr. A. C. Sirlat		
Mr. Chas. F. Bales	Chief Inspector, Borough of Queens	
Mr. E. T. Cunningham	Assistant Superintendent of Buildings, Borough of Queens	
Mr. John W. Moore	Superintendent of Buildings, Borough of Queens	
Mr. A. G. Hillberg	Representing	*Engineering Record*
Mr. J. W. Owen	,,	J. B. King & Co.
Mr. Henry Brown	Assistant Superintendent of Buildings, Borough of Richmond	
Mr. Edw. Wilkinson	Assistant Superintendent of Buildings, Borough of Brooklyn	
Mr. Wm. S. Devery	Former Chief of Police	
Mr. A. E. Klotz	Representing	A. E. Klotz Fireproofing Co.
Mr. Herman Ahrens		
Mr. H. G. Ebsary	,,	Ebsary Fireproofing Co.
Mr. H. F. Dorchester	,,	Ebsary Fireproofing Co.
Mr. Virgil G. Marani	,,	United States Gypsum Co.
Mr. Geo. Strehan	Bureau of Buildings, Manhattan	
Mr. S. G. Webb	Representing	Keystone Fireproofing Co.
Mr. J. W. Stromberg	,,	Clinton Wire Cloth Co., Chicago
Mr. H. F. Maurel	,,	Stanley Gollick Co.
Mr. W. Klingberg	,,	Clinton Fireproofing Co., of New England
Mr. Allen C. Beals	,,	*Record and Guide*, New York
Mr. O. J. Bloss	,,	Reliance Architectural Iron Works
Mr. Henry A. Millett	Insurance Broker	
Mr. R. D. Bradbury, C.E.	Boston, Mass.	
Mr. H. Kellar	Representing	*Scientific American*
Mr. Jas. S. MacGregor	Columbia University	
Mr. Lewis R. Ferguson	Representing	Association American Portland Cement Manufacturers
Mr. Thos. Heatley	Inspector, Bureau of Buildings, Borough of Bronx	
Mr. A. E. Herbst	Chairman Building Code Committee, Board of Aldermen	
Mr. Ernest W. Bradbury	Secretary Committee on Building Code, Board of Aldermen	
Mr. W. W. Bale	Representing	Coplay Cement Mfg. Co.
Mr. Eugene W. Stern, C.E.		
Mr. E. M. Lee	Engineers and Architects	
Mr. Geo. Hewitt		
Mr. J. M. Gibson, C.E.		
Mr. John F. Taggart	Business Agent, Metallic Lathers' Union	
Mr. Leonard Klink	Business Agent, Metallic Lathers' Union	
Mr. W. Earl Klingberg	Representing	Clinton Fireproofing Co., of New England
Mr. Geo. J. Jorge	,,	Bell Fireproofing Co.
Mr. P. A. Coons	,,	American Steel & Wire Co.
Mr. L. Bronk	,,	Edison Portland Cement Co.
Mr. G. D. Williams	,,	Mason's Supplies
Mr. Lovell H. Carr	,,	Alpha Portland Cement Co.
Mr. E. B. Fraser	Advertising Manager Clinton Wire Cloth Co.	
Mr. Geo. B. Hill	Representing	*Record and Guide*
Mr. C. E. Palmer	,,	*Scientific American*
Mr. J. C. Snackenberg	Chief Engineer Bureau of Buildings, Borough of Brooklyn	
Mr. M. J. Kennedy	Chief Inspector, Bureau of Buildings, Borough of Brooklyn	
Mr. W. D. Richards	Chief Clerk, Bureau of Buildings, Borough of Brooklyn	
Mr. S. H. Keyes	Representing	American Steel & Wire Co.
Mr. D. E. Hinman		

Mr. Robert E. Carrick	Representing	Fireproof Products Co.
Mr. C. A. Jackson	,,	Donn Barber
Mr. Wm. N. Beach	,,	Pennsylvania Cement Co.
Mr. Jas. E. Adkin	,,	Pennsylvania Cement Co.
Mr. H. D. Kerr	,,	Atlas Cement Co.
Mr. J. F. Miller	,,	Lawrence Cement Co.
Mr. Chas. C. Dominge	,,	German-American Fire Insurance Co.
Mr. Ira H. Woolson	,,	National Board of Fire Underwriters
Mr. F. J. Stewart	,,	New York Board of Fire Underwriters
Mr. Chas. F. Fairbanks, Jr.	,,	Assistant Treasurer Clinton Wire Cloth Co.
Mr. D. F. Bartlett	,,	United States Gypsum Co.
Mr. John J. Fogarty		
Mr. Lester W. Schwarz	,,	Clinton Fireproofing System
Alderman Robt. F. Downing		
Alderman John S. Gaynor		
Mr. Harry W. Bell	,,	Bell Fireproofing Co.
Mr. J. S. Seguine	,,	J. B. King & Co.
Mr. Rudolf P. Miller	Superintendent of Buildings, Borough of Manhattan	
Mr. Henry C. Turner	Representing	Turner Construction Co.
Mr. Daniel D. Mahoney	,,	Wells-Newton Co.
Mr. Archie W. Schwartz	,,	Jas. F. Egan
Mr. E. B. Goode, Jr.	,,	Lehigh Portland Cement Co.
Mr. Alfred Ludwig	Chief Inspector, Bureau of Buildings, Borough of Manhattan	
Mr. G. E. Escher	Representing	White Fireproofing Co.
Mr. R. S. Johnston	,,	Keystone Fireproofing Co.
Mr. Robt. E. Moss, C.E.		
Mr. Leigh Schofield		

Details of the test were carried out by Messrs. H. P. Banks, F. Miller and H. E. Slade.

Respectfully submitted,

(Signed) HAROLD PERRINE.

Log of Temperature Readings
Fire Test
Cinder Concrete, Terra Cotta, and Gypsum Floor Arches

Temperatures read by F. Miller, C.E.

July 30, 1913

Time	Couple No. 1 Cinder Concrete	Couple No. 2 Terra Cotta	Couple No. 3 Gypsum	Time	Couple No. 1 Cinder Concrete	Couple No. 2 Terra Cotta	Couple No. 3 Gypsum
10.50	Test Started			56	1820	1462	1870
10.53	348	178	458	59	1838	1572	1731
56	635	----	782	1.02	1860	1681	1843
59	820	----	971	05	1827	1781	1881
11.02	1010	----	1239	08	1659	1659	1870
05	1037	----	1379	11	1659	1631	1817
08	1048	----	1456	14	1723	1541	1720
11	1277	----	1420	17	1820	1637	1602
14	1209	----	1375	20	1863	1680	1784
17	1363	----	1334	23	1831	1637	1838
20	1392	---	1316	26	1723	1616	1784
23	1350	----	1360	29	1680	1552	1699
26	1393	----	1382	32	1734	1505	1602
29	1446	----	1436	35	1756	1505	1763
32	1521	----	1479	38	1838	1640	1784
35	1521	----	1489	41	1964	1700	1795
38	1399	1277	1356	44	1752	1590	1752
41	1409	1225	1356	47	1956	1660	1720
44	1538	1320	1366	50	1988	1770	1935
47	1656	1480	1517	53	1967	1770	1856
50	1726	1470	1592	56	1935	1750	1945
53	1731	1259	1613	59	1938	1739	1892
56	1653	1259	1635	2.02	1883	1685	1805
59	1828	1345	1689	05	1865	1647	1719
12.02	1860	1366	1785	08	1751	1569	1601
05	1839	1388	1753	11	1891	1638	1708
08	1774	1377	1753	14	1944	1790	1826
11	1731	1345	1774	17	1859	1714	1869
14	1828	1423	1753	20	1655	1601	1859
17	1613	1372	1699	23	1655	1590	1751
20	1667	1450	1570	26	1805	1708	1644
23	1762	1474	1676	29	1987	1783	1655
26	1719	1400	1708	32	1977	1837	1837
29	1622	1408	1719	35	1826	1801	1859
32	1848	1504	1773	38	1851	1730	1794
35	1891	1483	1773	41	1851	1665	1816
38	1837	1504	1816	44	1795	1569	1708
41	1883	1569	1869	47	1858	1622	1762
44	1808	1618	1869	50	1808	1622	1762
47	1837	1615	1740				
50	1916	1636	1805	Average Temp.	1674	1566*	1652
53	1809	1484	1870				

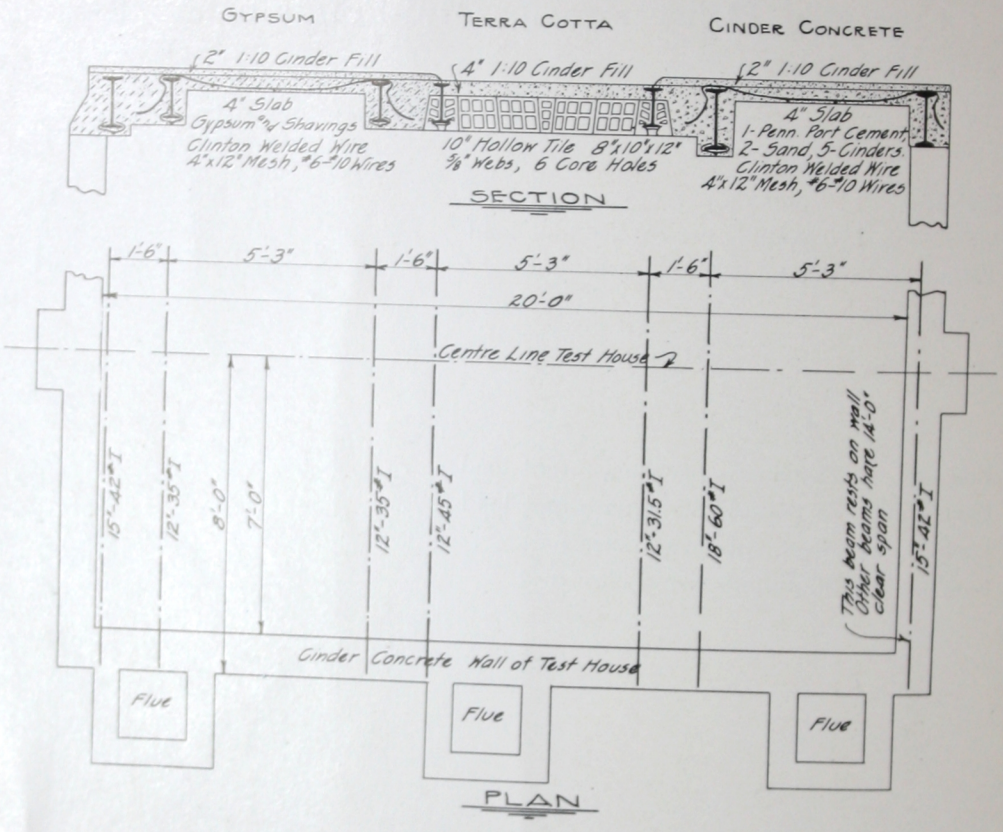
*Temperature readings at center of Terra Cotta Arch between 10.56 and 11.35 were lost, due to the fact that the couple at this point was not reading properly. A new couple was inserted at 11.38 and it is from that time until the end of the test that this average is taken.

APPENDIX III

Corrected Deflections for Mid-Points of Arches

	Cinder Concrete	Terra Cotta
End fire, 150 pounds per square foot load	$\frac{3}{8}$ "	$1\frac{3}{16}$ "
Floor cool, 150 pounds per square foot load	$\frac{1}{8}$ "	$\frac{3}{8}$ "
Total load, 600 pounds per square foot	$\frac{9}{32}$ "	$\frac{47}{64}$ "

	Gypsum
End fire, 75 pounds per square foot load	$\frac{1}{16}$ "
Floor cool, 75 pounds per square foot load	$\frac{3}{16}$ "
Load, 450 pounds per square foot	$\frac{5}{8}$ "
Load, 496 pounds per square foot	Failure



CONSTRUCTION DETAILS OF FLOOR SLABS

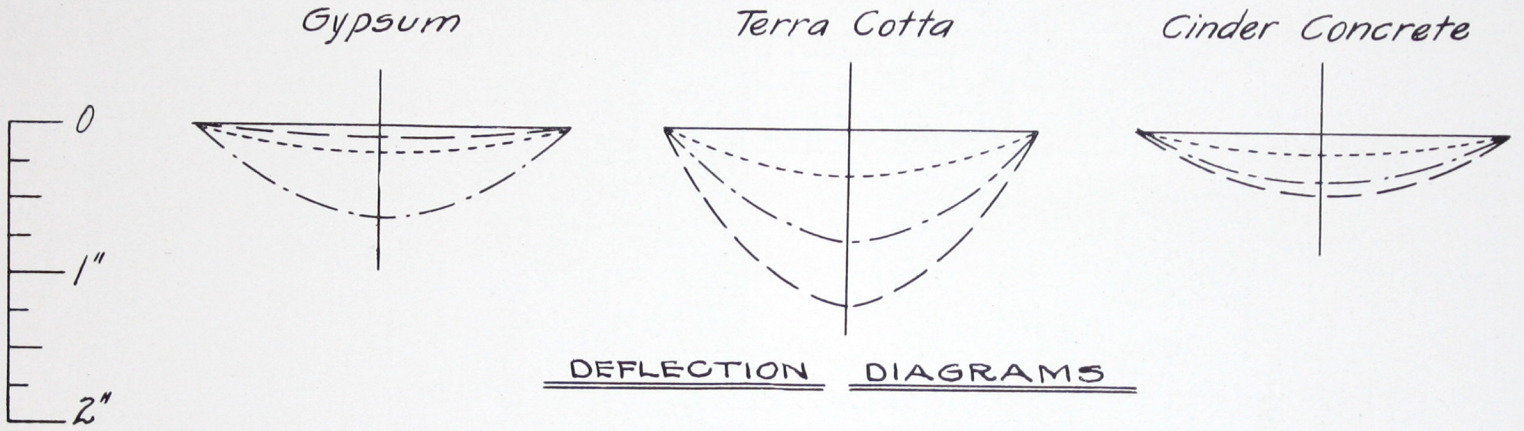
It will be noted that the cinder concrete slab is practically exterior panel construction, as it is supported by one beam only on the wall side. The gypsum slab has a two beam support on the wall side with a good end restraint and anchorage for the reinforcement. In this respect the terra cotta arch occupies the most advantageous position, as it is restrained on either side by the cinder concrete and the gypsum slabs.

———— Initial Position and after load of 150 # per sq. ft. (Gypsum 75 # per sq. ft.)

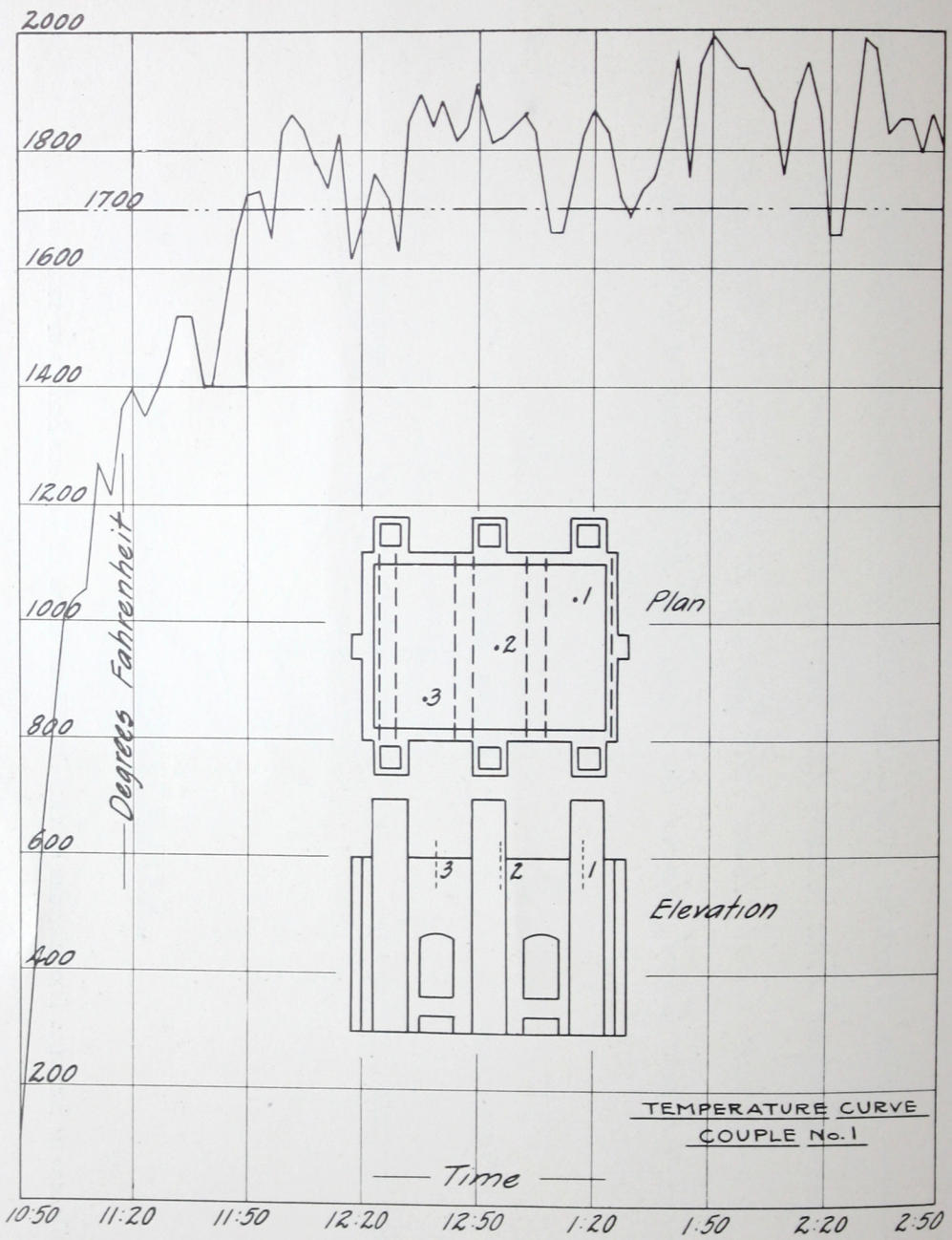
– – – – – – End of Fire, load 150 # per sq. ft. (Gypsum 75 # per sq. ft.)

..... Floor Cool, load 150 # per sq. ft. (Gypsum 75 # per sq. ft.)

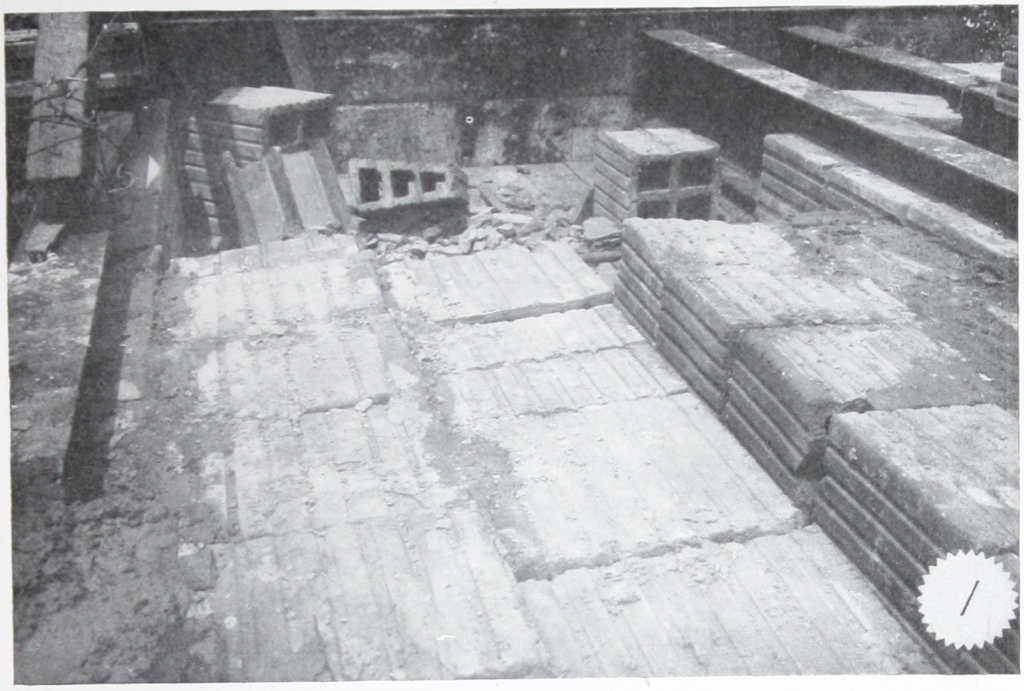
—·—·—·— Floor Cool, load 600 # per sq. ft. (Gypsum 496 # per sq. ft.)



Diagrams Showing Deflections of the Different Slabs at Various Stages of the Test

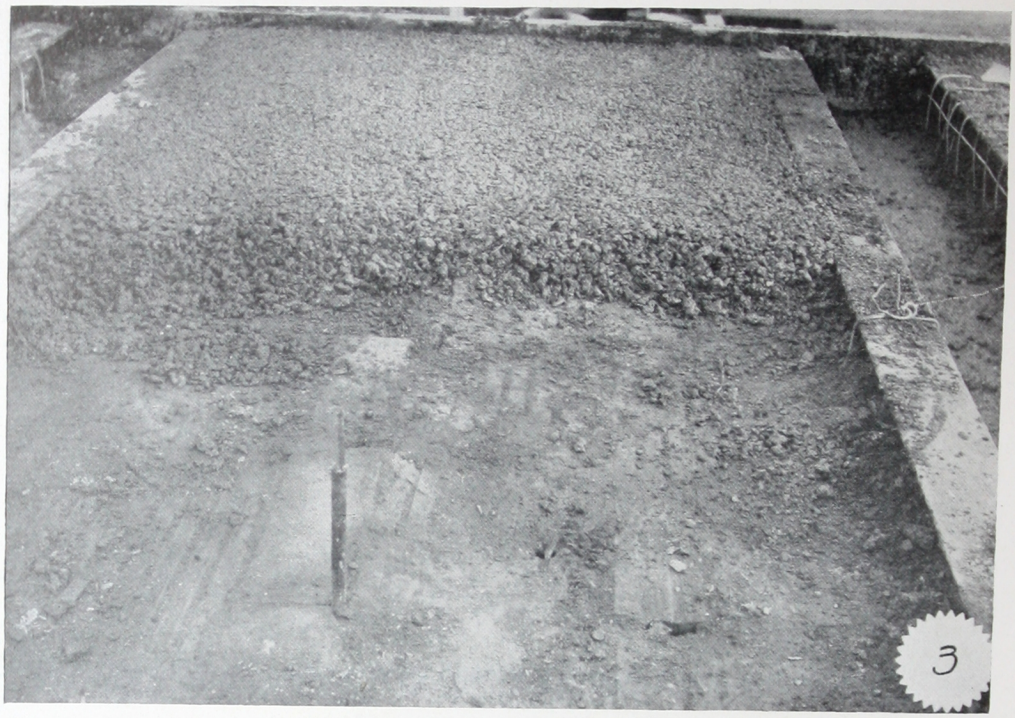


Temperature Curve, Couple No. 1, and Sketch Showing Location of Thermo-couples

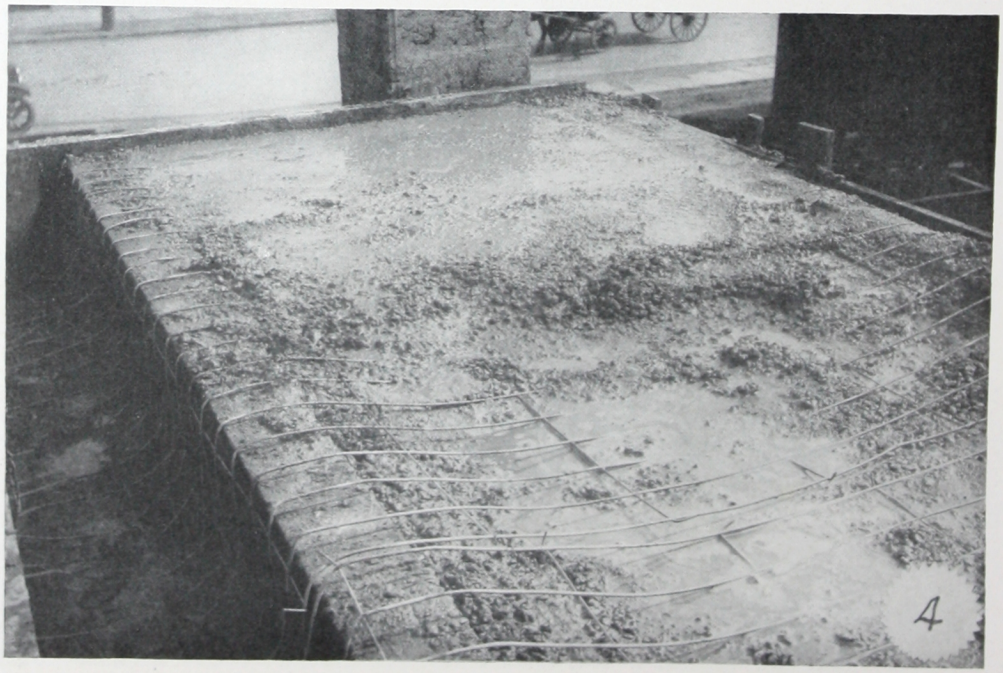


No. 1. Installation of Terra Cotta Arch

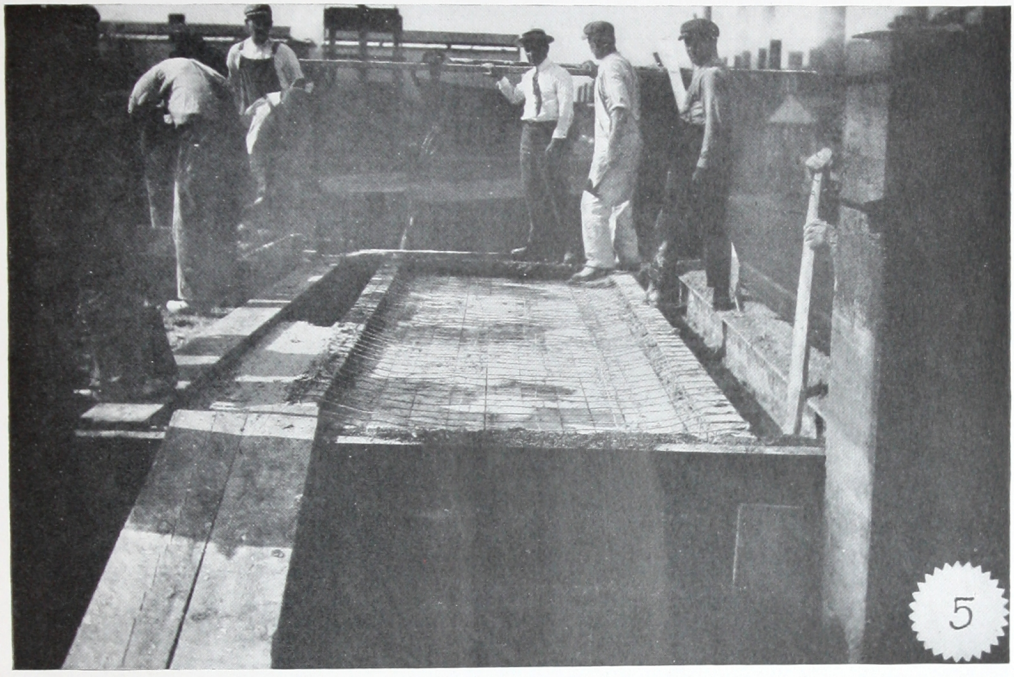
No. 2. Terra Cotta Arch, Showing Metal Strips on Forms to Produce Camber and One Tie Rod



No. 3. Placing of Cinder Fill on Terra Cotta Arch

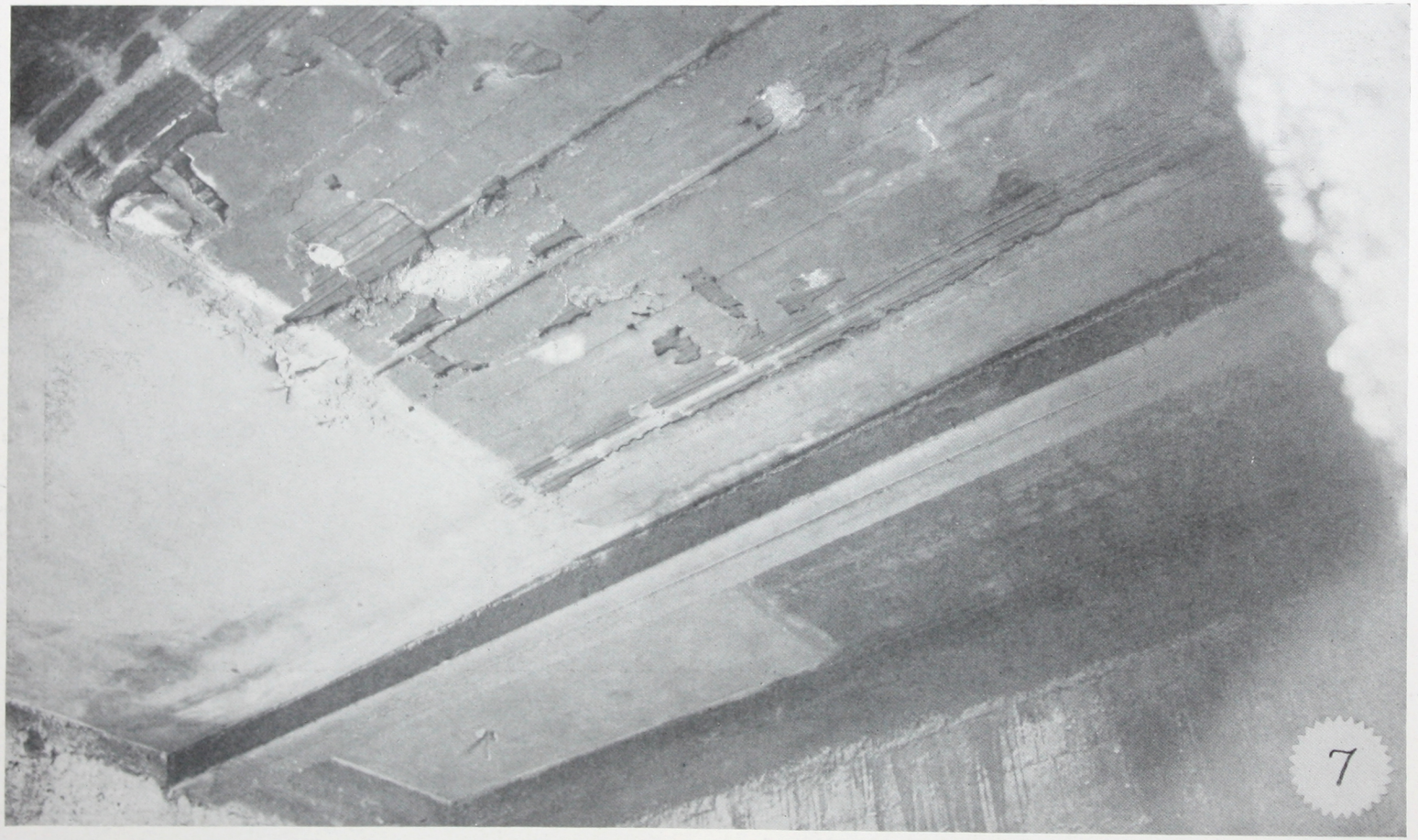


No. 4. Installation of Cinder Concrete Slab, Showing Clinton Electrically Welded Wire in Place



No. 5. Installation of Gypsum Slab, Showing Clinton Electrically Welded Wire in Place

No. 6. Depositing the Gypsum and Shavings Mixture for Gypsum Slab

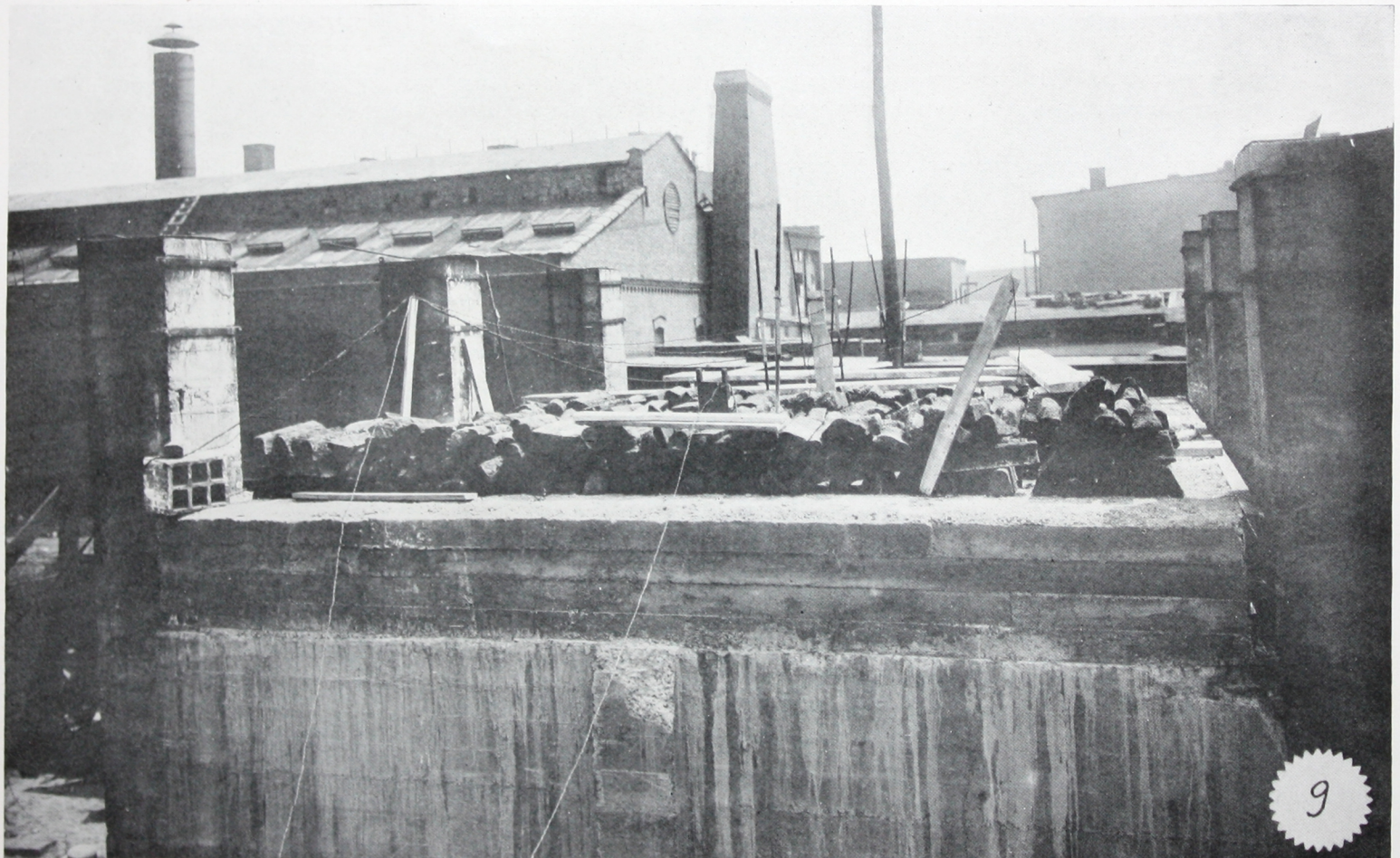


No. 7. Under Side of Terra Cotta Arch with Cinder Concrete Slab in Background

View taken before the fire, showing mortar joints and impressions of metal camber strips in terra cotta arch. Thermo-couple tubes are shown in each arch and plaster covering on one-half the length of each arch.

No. 8. Under Side of Floor with Gypsum Slab in Background, Showing Complete Plaster on this Slab

It will be seen from this view and also from Photograph No. 7 that while one-half of the terra cotta and cinder concrete slabs were plastered, the unplastered portion of the terra cotta arch has a very substantial coating of cement mortar. This is mortar which was slushed in under the blocks while the arch was being laid. This mortar was about ½″ thick and, as the photographs show, practically covered all the blocks. This cement mortar no doubt served as a very efficient protection to the blocks against the effect of the fire.

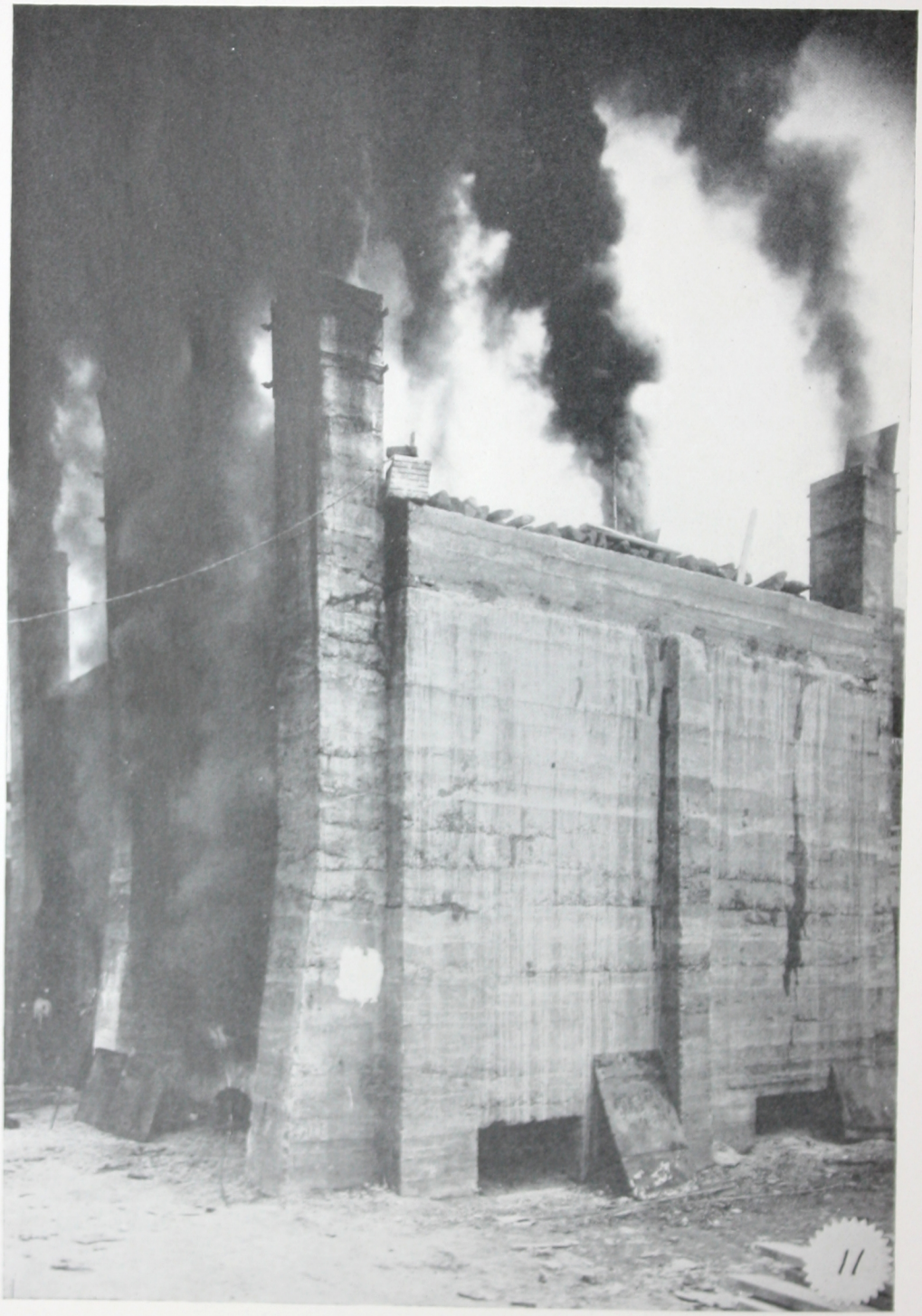


No. 9. Initial Load of 150 Pounds per Square Foot on Terra Cotta and Cinder Concrete Slabs and 75 Pounds per Square Foot on Gypsum Slab

This view shows deflection gages and pyrometer leads in place ready for beginning the test.

No. 10. View of Test House at Starting of Fire

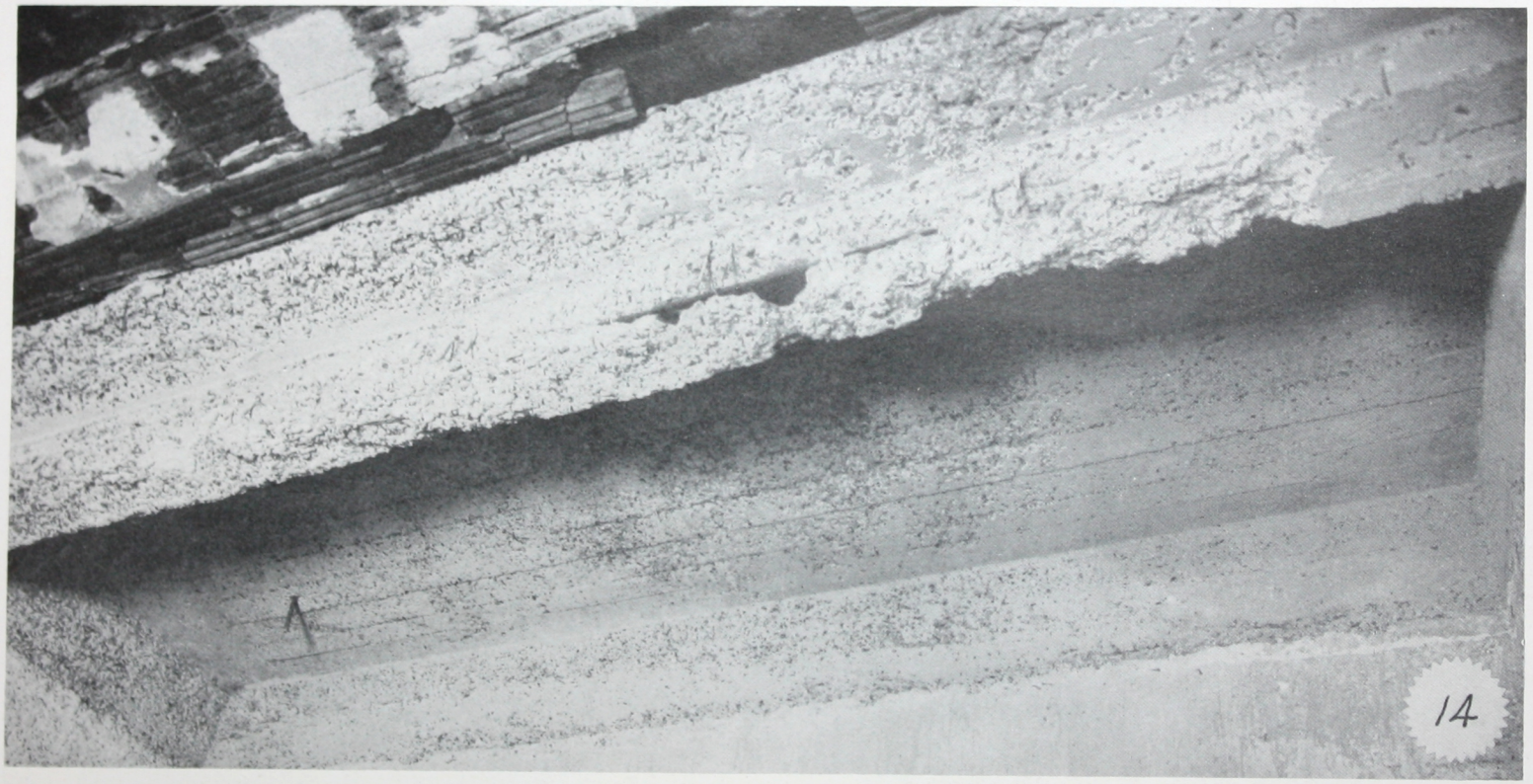
The firing was done through the door shown in this view and through a similar opening on the other side of the center flue. As the fuel was thrown in through these side doors, the tendency was to fire with greater intensity under the outside slabs ; that is, the gypsum and the cinder concrete slabs. Reference to the log of temperature readings on page 10 will show that the average temperature under the terra cotta arch throughout the test was about 100° less than under the other slabs. The defective pyrometer as there noted eliminated the temperatures under the terra cotta arch for the first thirty-nine minutes of the firing. The average temperature of 1566° therefore represented the average heat after it had reached an intensity of nearly 1300°. If the lower readings represented by the early stages of the firing had been included, this average of 1566° would have been further reduced. The records, therefore, show that the gypsum and cinder concrete arches were actually subjected to an average temperature of more than 100° in excess of the temperature under the terra cotta arch.



No. 11. View of Test House during Fire, Showing All Flues Active

No. 12. Application of Water against Under Side of Slabs

No. 13. Application of Water, Showing Direction and Evident Power of Stream

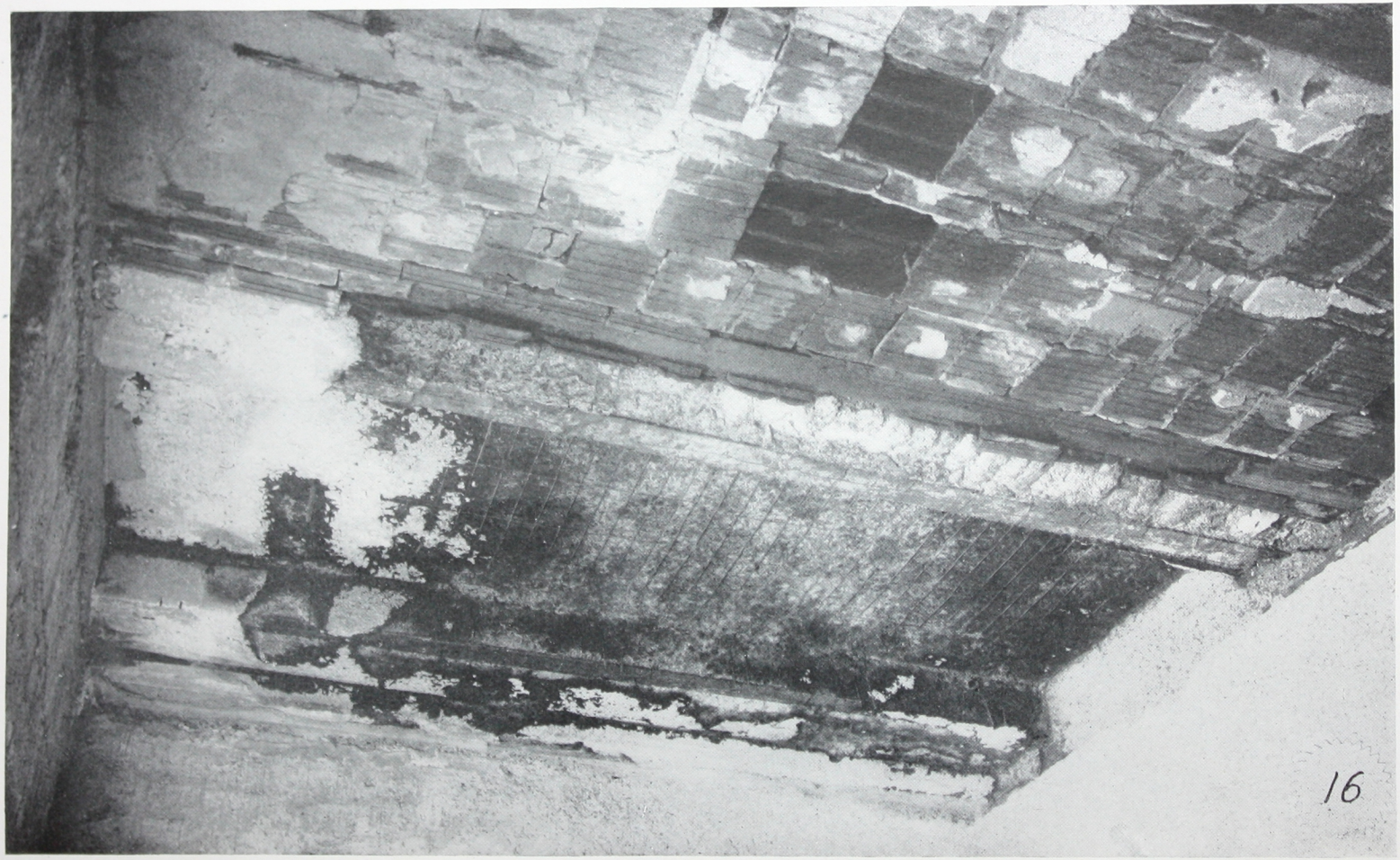


No. 14. Cinder Concrete Slab after Fire and Water

This view shows the removal of all plaster and the slight pitting of the concrete surface. The deep I-beam shown in this view is the 18″ I-beam as shown in the details of construction. Owing to the depth of this beam, the lower flange formed a ridge projecting below the under surface of the floor. The concrete protection around this lower flange was, therefore, subjected to the worst possible conditions of fire and water. The slight mutilation of this concrete protection shows how efficiently the concrete and the Clinton Welded Wire beam wrapping withstood the effects of the fire and water.

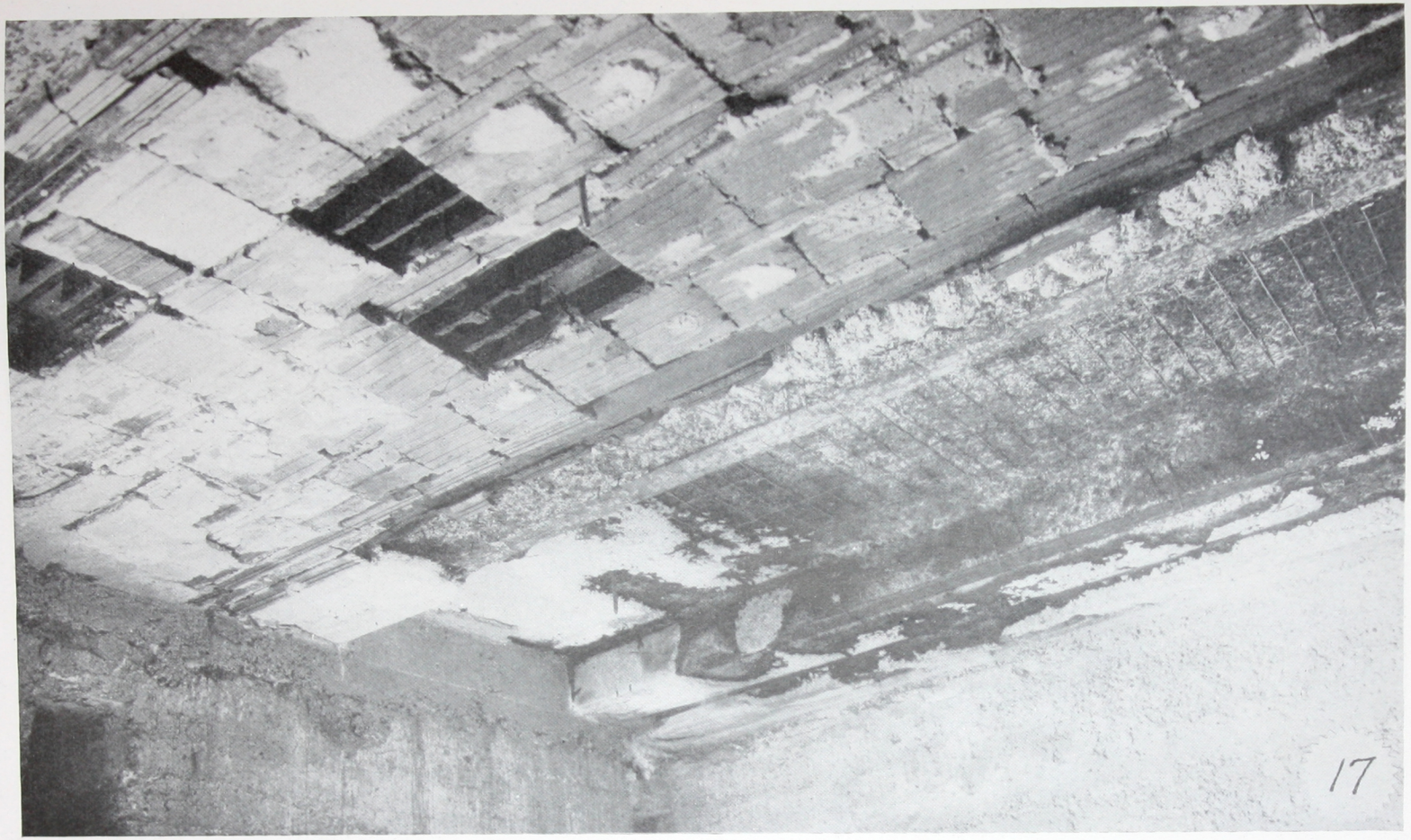
No. 15. Terra Cotta Arch after Fire and Water

This view shows an almost complete destruction of the terra cotta beam protection and the destroyed lower webs of a number of the terra cotta blocks in the floor.



No. 16. Gypsum Slab after Fire and Water

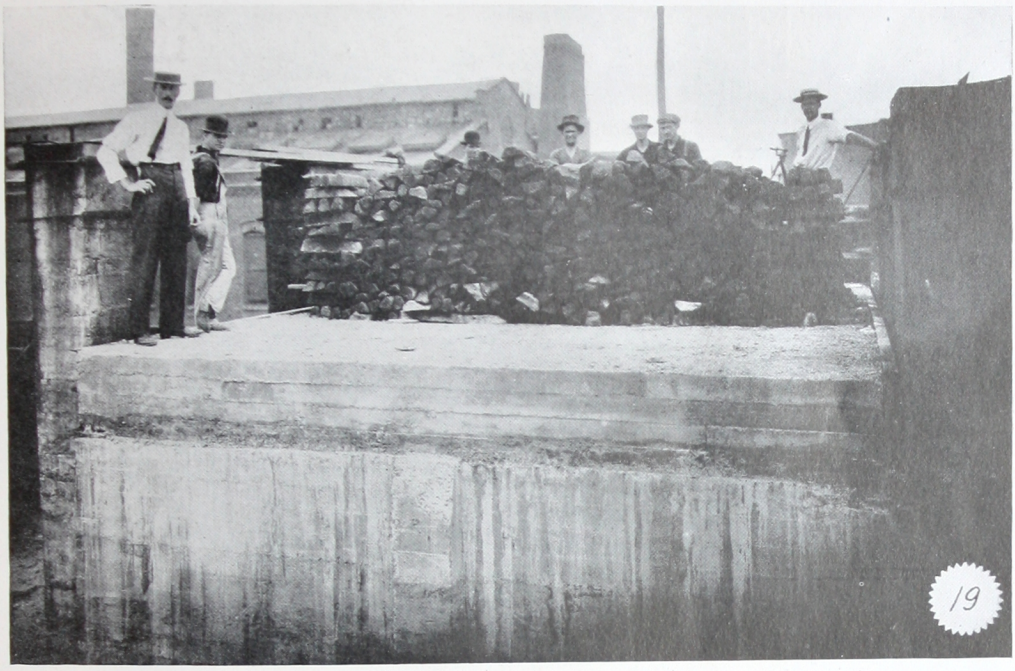
This view shows the removal of practically all material below the reinforcement and the destruction of the lower flange covering of I-beam.



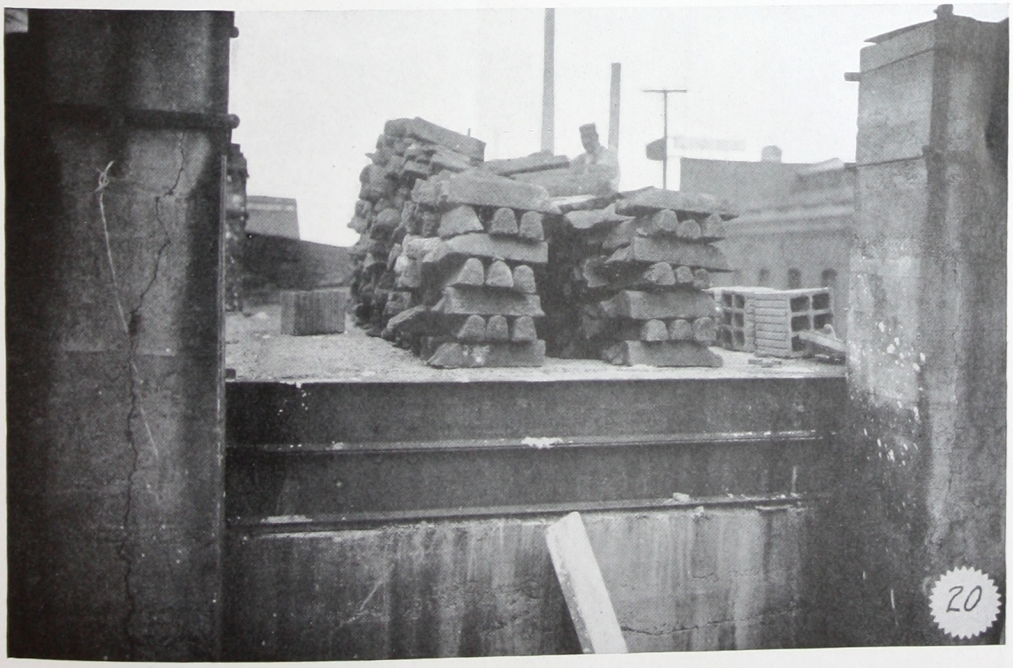
No. 17. Gypsum Slab after Fire and Water

This view shows some protection still adhering to wire near the front wall of test house where water could not strike.

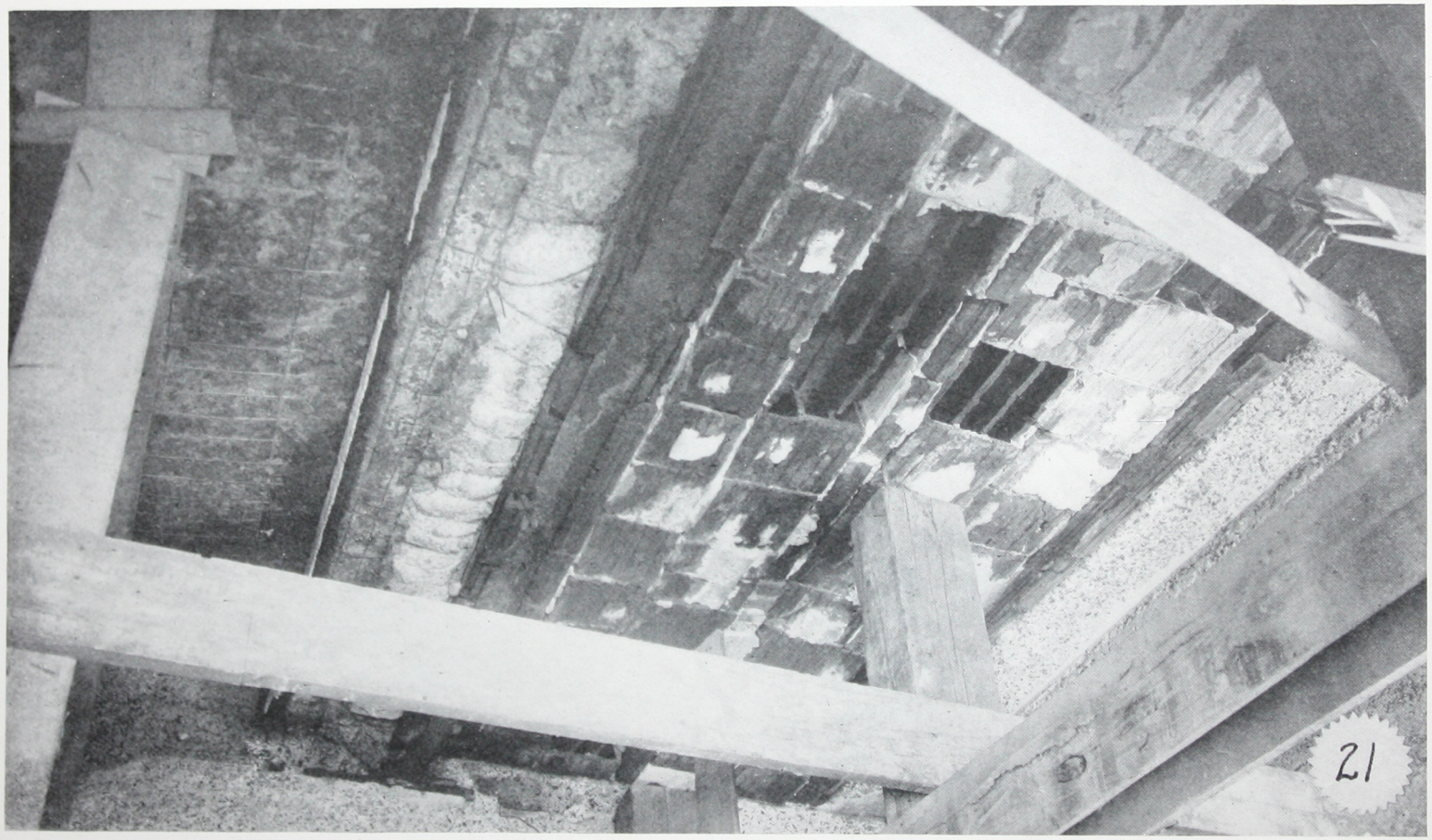
No. 18. Total Load of 600 Pounds per Square Foot on Cinder Concrete Slab



No. 19. Total Load of 600 Pounds per Square Foot on Terra Cotta Arch



No. 20. Total Load of 496 Pounds per Square Foot on Gypsum Slab



No. 21. Terra Cotta Slab after Load and Sound Test

After the final load of 600 pounds per square foot was applied, the under surface of the terra cotta slab was carefully examined. More than 75% of the lower webs of the blocks were found to be unsound and portions could be easily removed by hand.

The timber shoring shown in this view was installed to prevent collapse of the gypsum slab.

Borough of Brooklyn, The City of New York, August 6, 1913.

MR. P. J. CARLIN, *Superintendent of Bureau of Buildings:*

Sir: Following is a report of a fire, water and load test on three different kinds of floor arches installed in the test house of the Columbia University, at the northwest corner of Monitor Street and Norman Avenue, Brooklyn, on July 1, 1913.

The object of the test was to show the merits of the different constructions under the exact same conditions of test, the three different kinds being installed by one concern, a Mr. Oliver of the Clinton Wire Cloth Company, with office at 101 Park Avenue, Manhattan, N. Y., the installation being a fair sample of the manner in which the different arches are installed in general actual practice.

The arches were each 5′ 3″ wide and 14′ 0″ long.

One was a cinder concrete reinforced with Clinton Wire Cloth, 4″ x 12″ mesh, No. 6 and No. 10 wires. Depth 4″.

One was constructed of hollow terra cotta blocks with protecting skew-backs for the beam flanges. These skew-backs were not bedded against the beams. The blocks used were 10″ deep.

One was constructed of United States gypsum and mixed with wood mill shavings.

This arch was 4″ thick, reinforced with Clinton Wire Cloth, 4″ x 12″ mesh, No. 6 and No. 10 wires. A cinder concrete fill 2″ thick was put on top of the cinder concrete and the gypsum arches and about 4″ on top of the terra cotta arch. All the above-mentioned arches were put in on July 1, 1913.

After the removal of the centers one-half of the soffit of both the cinder concrete and the hollow terra cotta block arches were plastered with patent mortar (pearl hard mortar), and the entire soffit of the gypsum arch was plastered with the same mortar.

For the construction and general layout see accompanying blueprint.

The gypsum arch was found to be defective, as it did not set upright, and it was removed and replaced in the same manner as at first, on July 16, 1913, the replacing being witnessed by G. McMein. See attached report.

On July 29, 1913, a uniform load of 150 pounds of pig iron was placed on top of the cinder concrete arch, also on the terra cotta arch, and 75 pounds on the gypsum arch due to its age.

On July 30, 1913:

Fire was started at 10.50 A.M. and reached 1700° at 11.59.

Fire was started at 10.50 A.M. and reached 1731° at 12.59.
Fire was started at 10.50 A.M. and reached 1797° at 1.51.
(¾″ deflection on terra cotta arch.)
Fire was started at 10.50 A.M. and reached 1749° at 2.35.
Fire was started at 10.50 A.M. and reached 1770° at 2.48.
(1¼″ deflection on terra cotta.)

Water was applied at 2.51 through a city fire engine with 200 feet of hose and a 1⅛″ nozzle, a pressure of 60 pounds at the nozzle. Water was played on fire for 1½ minutes and then on the under side of arches for a minute, ½ in each of the doors of the test house, then again for a minute in each of the doors or 5 minutes. The top was then flooded for 3 minutes and then the under side of arches again for 5 minutes.

Effects of Fire and Water

July 30, 1913

Part of the plastering peeled off of the gypsum arch during the fire.
The deflections noted during the fire:

Cinder concrete	$\frac{3}{8}$″
Terra cotta blocks	$1\frac{3}{16}$″
Gypsum arch	$\frac{1}{16}$″

When water was applied all the plastering was removed from all the arches.

Of the protecting skew-backs of the terra cotta arch ¾ of them were removed on one beam and 3 of them on the other beam. Also the bottom wall of the block came off of 6 of them.

The concrete protection of I-beams was partly removed for a space of 4 feet, otherwise appearing uninjured.

The soffit of the gypsum arch was washed away slightly above the reinforcement for about 80% its length, also the beam protection.

July 31, 1913

A further survey of the effects of the fire and water showed the soffit of the cinder concrete arch slightly washed with water, but could be easily patched.

The terra cotta arch by tapping bottom face showed that 90% of bottom walls were cracked away from the rest of the block, some being easily removed by hand.

This arch could not be repaired to its original strength.

The loads on the "cinder concrete" and the terra cotta block arches were now increased to 600 pounds to the square foot, which both of them held.

The maximum deflection on cinder concrete under load, $\frac{9}{32}''$.

On the terra cotta arch, $\frac{47}{64}''$.

The gypsum arch was loaded to 496 pounds per square foot when it settled down about an inch on the temporary support placed under it for the protection of the men loading, and the load was stopped. The noted deflection at about 425 pounds per square foot was $\frac{5}{8}''$.

A statement will be furnished by Columbia University later, showing the deflections and temperature in detail.

Respectfully submitted,

(Signed) E. WILKINSON.

BUREAU OF BUILDINGS

CITY OF NEW YORK, BOROUGH OF QUEENS

HACKETT BUILDING

Long Island City, August 7, 1913.

MR. JOHN W. MOORE, *Superintendent:*

Dear Sir: By your order of July 1, 1913, I witnessed the installation of 3 floor arches at the Columbia University Testing Station, Norman Avenue and Monitor Street, Brooklyn, N. Y., for Albert Oliver, of 101 Park Avenue, Manhattan. See attached blueprint as to installation.

On July 16, 1913, the gypsum arch was removed and replaced under same conditions as shown on blueprint, under the supervision of Mr. Victor Marani, representing The United States Gypsum Company.

On July 29, 1913, 150 pounds per square foot was placed on the concrete and hollow block arches and 75 pounds per square foot on the gypsum arch. July 30, 1913, fire test applied: fire started at 10.50 A.M.; at 11.50 A.M., 1700°; at 12.59 P.M., 1751°; 1.51 P.M., 1797° average; at 2.35 P.M., 1749° average; at 2.48 P.M., 1770° average.

For deflection on arches during fire not ascertainable: at 2.50 P.M. water was applied to the under side of the arches for 5 minutes, then the top of the arches were flooded for 3 minutes, then again for 5 minutes to under side of arches, through 3″ hose and 1¼″ nozzle, with 90 pounds pressure at engine and about 60 pounds pressure at the nozzle. Top flooding at about 30 pounds pressure. Effect: plastering off gypsum during fire after water; all plastering off terra cotta arch; the bottom walls of 6 blocks came off on second application, also flange blocks off on one side terra cotta. Gypsum peeled to fabric, also protection of beam flanges.

On July 31, 1913, 44,100 pounds, or 600 pounds per square foot, was placed on concrete arch, and showed a reflection in center of the arch of $\frac{3}{16}$″.

On August 1, 1913, 44,100 pounds, or 600 pounds per square foot, was placed on hollow block arch, and showed a deflection in center of arch of ⅜″. Tapping the bottom soffits of blocks showed that the bottom wall or shell had cracked and was loose on at least 90% of the arch.

August 1, 1913, 36,483 pounds, or 496 pounds per square foot, was placed on gypsum arch and failed. At 400 pounds per square foot arch deflected ⅝″.

NOTE.—Gypsum whole arch plastered. Concrete and hollow block arches, south half of arch plastered. Did not witness the mixing or applying of plaster.

(Signed) AUGUST C. SIEBERT.

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